Development and Assessment of a Dynamic Human-Computer Interface Prototyping Environment With Embedded Evaluation Capability

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Purpose

The purpose of this research is to develop and assess a Human-Computer Interface (HCI) prototyping environment that includes: 1) an HCI format development tool; 2) a test and evaluation simulator development tool; 3) a dynamic, interactive interface between resultant HCI's and simulators; and 4) an embedded capability to evaluate the HCI based on a user's performance.

Background

Many of the activities and functions at the MSFC, and for that matter throughout the Agency, take place via a computer interface. Commercially available applications (e.g., word processors, spreadsheets) come with their own HCI's. However, since much of the work at MSFC is with specialized, unique, and/or prototype systems and processes, unique HCI's must be developed and tailored to that specific application or environment. In many cases, the HCI's must be either developed prior to the completion of a fully functioning target system or process, or developed isolated from the existing system/process. In both instances, the HCI requirements must be developed without the benefit of interacting with the target system or process. At MSFC, these include HCI's at the various test stands and labs, on the various Huntsville Operations Support Center (HOSC) and Payload Operations Control Center (POCC) consoles, on the Spacelab Payload and General Support Computer (PGSC), and soon, on the *International Space Station* Payload Operations Integration Center (POIC) consoles and onboard payload workstations.

With the advent of today's advanced graphical user interfaces (e.g., icons, pop-up menus, virtual control and display panels, etc.), the user's ability to monitor and control systems and processes can be greatly enhanced through proper attention to the "look and feel" of the HCI. Thus, the process to develop the HCI requirements/specifications has gained increased importance. Ideally, this process should employ an iterative "test and revise" methodology where the design requirements are developed and extensively refined before design implementation, minimizing costly (e.g., money, time) rework of requirements and/or design that can occur during later phases. Software development problems usually occur during requirements specification and it is here that elaborate feedback loops are needed though seldom provided.[1]

Prototyping is a methodology based on an evolutionary perspective of HCI development, producing early operative versions (prototypes) of the HCI's for subsequent evaluation and revision.[1] There are two basic approaches to prototyping: "static" and "dynamic."[2] Static prototyping provides HCI's that can be demonstrated, but not used directly. This approach does not include the functionality of the target process or system. Dynamic prototyping results in a testable simulation that provides a fully functional HCI that can be "test flown" by the end user[3] and enables interactive usability studies and acceptance testing. The goal of prototyping, usability studies, acceptance testing, etc., is to force as much of the evolutionary development as possible into the preimplementation phase, when modifications are relatively easy and inexpensive.[4]

There are four key tools or capabilities necessary for the dynamic prototyping process. First, a tool is required to build and spatially arrange the various buttons, widgets, icons, menus, etc., that populate a computer display. A second tool is required to develop a simulation of the target system or process. Although the resultant simulation does not require the fidelity of a training simulator, it must simulate enough of the relevant functional attributes of the target system or process to enable usability studies and acceptance testing. Third is the capability to provide a dynamic, interactive interface between the prototype HCI, developed with the first tool, and the simulation of the target system or process, developed with the second tool. Thus, for example, when a "Power Fan ON" icon on the display is selected, the related "Fan RPM" gauge on the display increases and the "Temperature" gauge decreases. At project start, the existing capability that came closest to this is the interactive link between the Computer Applications and Virtual Environments (CAVE) Laboratory and the Payload Crew Training Complex (PCTC), where prototype displays could be developed and linked to existing Spacelab training simulators. The utility of employing this capability as a dynamic prototyping environment is diminished because the training simulators are delivered too late to be effectively used in prototyping the displays.

The fourth key capability, an extremely important aspect of the prototyping process, is the ability to evaluate the adequacy of the prototype HCI's. If done correctly, the evaluation not only determines that an HCI is deficient, but points to specific aspects or attributes of the HCI that need improvement. This includes not only verifying compliance to applicable styles, guidelines, and standards, but also measuring the adequacy of the HCI to enable the user to control and maintain situational awareness of the target system or process. Adequacy, or usability, measures would consider such performance attributes as the type and frequency of errors, time and context of calls to <Help>, subtask completion times, response times, etc.

Approach

Six tasks were planned to accomplish the objectives of this project. In the first task, the necessary additional hardware and software was procured. The HCI format development tool (SAMMI) was already available in the CAVE Lab. PERCNET, a user-centered, knowledge-based modeling and simulation application and its hosting platform (SUN SPARCStation 10GX) was procured. Requirements for a SAMMI-to-PERCNET "bridge" was developed and the code providing this functionality procured.

During task two, a candidate target system (automobile) was identified and relevant data and information gathered. Preliminary requirements for the HCI's, simulator, evaluation metrics, and approaches to embedding the evaluation metrics were to be developed. Task three began with the delivery of the hardware and software. During this phase, installation, systems integration, check-out, and familiarization occurred.

Task four began the iterative process of developing and refining the HCI's, simulator, and evaluation metrics for the target system. The HCI's and simulator were linked through a dynamic, interactive interface. This task ended with an assessment of the functionality and performance of the simulator, HCI's, and SAMMI-to-PERCNET "bridge." During task five, the evaluation metrics were implemented and assessed. Task six involved empirically assessing the integrated dynamic HCI prototyping environment with embedded evaluation capability.

Accomplishments

During the past year, the HCI's, simulator, and SAMMI-to-PERCNET "bridge" were refined and assessed. The system provided the necessary functionality; however, the simulator performance (response time) was not sufficiently fast enough to satisfy HCI response requirements. In fairness, PERCNET was originally developed as a Human-System Integration analysis tool, where initial conditions were input and the system ran a closed simulation until completion. Speed was not a driving requirement. This project opened up the simulation for real-time interaction with an HCI. Even though this particular simulation tool proved ultimately unsuitable for its function in this project, other tools are commercially available that should provide the necessary functionality and performance. To continue this project (specifically to assess the embedded evaluation metrics), the PERCNET simulation application has been replaced with C code to provide the necessary functionality at the required response latency. Evaluation metrics were developed and embedded in the system. The experimental design, methodology, and the dependent and independent variables have been defined and operationalized. The assessment and refinement of the embedded evaluation metrics have been completed. The experimental sessions of the empirical study of the system have been completed (32 subjects, 4 runs each).

Planned Future Work

The last tasks are to reduce and analyze the data and prepare the final report.

Funding Summary ($k)

	FY97	**FY98**	**Total**
Authorized:	71.0	22.0	93.0
Obligated:			
H/W:	12.1	4.2	16.3
S/W:	37.5	3.8	41.3
Auburn Contract (NAS8–39131):	14.5	13.3	27.8
SFFP:	7.0		7.0
Total:	71.1	21.3	92.4

Status of Investigation

Project approval was received on October 1, 1992. The estimated completion date is Spring 1998. This task will continue in FY98 with no additional funds.

References

[1]Budde, R.; Kautz, K.; Kuhlenkamp, K.; Züllighoven, H.*: Prototyping: An Approach to Evolutionary System Development*, New York: Springer-Verlag, 1991.

[2]Harken, S.: "Requirements Specification and the Role of Prototyping in Current Practice," In *J. Karat* (Ed.), *Taking Software Design Seriously: Practical Techniques for Human-Computer Interaction Design*, pp. 339–354, Boston: Academic Press, 1991.

[3]Rouff, C.; and Horowitz, E.: "A System for Specifying and Rapidly Prototyping User Interfaces," *In J. Karat* (Ed.), *Taking Software Design Seriously: Practical Techniques for Human-Computer Interaction Design*, pp. 257–271, Boston: Academic Press, 1991.

[4]Shneiderman, B.: *Designing the User Interface*. Reading, Massachusetts: Addison-Wesley, 1992.